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COOLING ELECTRONIC EQUIPMENT AT SIMULATED HIGH ALTITUDE IN HYPOBARIC CHAMBERS

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

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An air cooling system has been designed to minimize electronic equipment failures during simulated exposures to 9,000 meters (29,000 ft) in hypobaric chambers. Air density, critical to convective heat transfer during electronic equipment operations, diminishes rapidly below 830 grams/meter^3 (16,000 ft, 5,000 meters) resulting in equipment failures. Forced convection, using fans, can be effective up to 6,000 meters but extensive equipment failures occur at higher altitudes. A newly designed cooling system incorporates a micrometer- like airflow control nozzle that directs compressed air onto the subject area . The design also accelerates surrounding air molecules to create a highly amplified flow by adding the entrained ambient air to the compressed air. Air flows may be directed on heat exchangers, power supplies, through ventilation ports, to assist fan units, and for general in-cabinet cooling.

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COOLING ELECTRONIC EQUIPMENT AT SIMULATED HIGH ALTITUDE IN HYPOBARIC CHAMBERS

JAMES A. DEVINE

FOREWARD

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ABSTRACT

An air cooling system has been designed to minimize electronic equipment failures during simulated exposures to 9,000 meters (29,000 ft) in hypobaric chambers. Air density, critical to convective heat transfer during electronic equipment operations, diminishes rapidly below 830 grams/meter^3 (16,000 ft, 5000 meters) resulting in equipment failures. Forced convection, using fans, can be effective up to 6000 meters but extensive equipment failures occur at higher altitudes. A newly designed cooling system incorporates a micrometer- like air-flow control nozzle that directs compressed air onto the subject area. The design also accelerates surrounding air molocules to create a highly amplified flow by adding the entrained ambient air to the compressed air. *Air flows may be directed* on heat exchangers, power supplies, through ventilation ports, to assist fan units, and for general in-cabinet cooling.

INTRODUCTION

Hypobaric chambers are facilities that simulate the earth's atmospheric conditions through the reduction of barometric pressure using vacuum pumps (1). Such facilities have been employed in the field of medical research for the study of adaptive life processes of humans and animals, in industry for environmentally stressing materials and hardware, and for flight crew and space mission training. Whether it be equipment testing, personnel training, or research and development activities inside these hypobaric facilities, it is often necessary to expose electronic equipment and data collecting instrumentation for the purpose of making measurements and testing equipment. Until recently, data collection was limited by the height of the altitude, the duration of exposure, and the restricted capacity to cool instrumentation. All of these factors contribute to the failure rates of electronic equipment operated at simulated high altitude.

This report discusses the reasons for electronic equipment failures at high altitudes, the current practice employed to extend the operational ceiling, and a new technology that not only prolongs operational specifications and expectations but allows the use of such equipment at altitudes previously not attainable.

BACKGROUND

Failure of instrumentation and other electronic equipment at high altitude more than likely may be traced to elevated operating temperatures resulting from a reduction in air density. The physical parameters and background information on the evolution of this problem and the proposed solution is described.

In the earth's atmosphere, gases are attracted earthward by gravity, exhibiting high pressure close to the surface with rapidly decreasing pressure as one moves further away from the surface. Air density exhibits a barometric pressure of 760 millimeters of mercury (mmHg) at sea level. Barometric pressure decreases with increasingly higher altitudes such that at 5500 meters (18,000 ft) it is approximately one-half (380 mmHg) that of sea level. While at 10,000 meters (32,000 ft) the pressure is nearly one-fourth the atmosphere or 210 mmHg. Air density then, is the state of compacted gas molecules as the result of the earth's gravitational force and the resulting weight of the air mass above. It is described as the mass per unit volume which is calculated to be 1220 grams/meter^3 (gm/m^3) at sea level and rapidly decreases to 425 gm/m^3 at 10,000 meters (2). Therefore, it can be said that air density decreases proportionately to barometric pressure and inversely to altitude as measured in meters or feet. In a hypobaric chamber, the decrease in air density can be simulated simply by removing some of the air with a vacuum pump until the desired atmospheric pressure has been reached.

As air density decreases, convective heat transfer properties of air also diminish. Convection is the transfer of heat between a moving medium (i.e. a gas) and a surface, or the transfer of heat from one point to another by movements within the gas (3). In convection, if the gas moves because of a difference in density resulting from temperature change, the process is called "natural convection" or "free convection". If gas is moved by mechanical means (pumps or fans) the process is called "forced convection".

In the flow between a gas and a solid, there always exists a thin film which tends to cling to the surface as a relatively stagnant layer and which acts as an additional resistance to heat flow. The thickness of this film is greatly influenced by the convection conditions surrounding the surface. For example, a fan moving air (forced convection) past a heated surface greatly enhances heat displacement over the more stagnant condition that occurs during natural convection, especially at reduced barometric pressure. Because of the many variables involved (temperature, wind velocity, surface configuration, mass per unit volume of the circulating medium), exact calculation of heat transfer through such films is in most cases improbable and over-all heat-transfer coefficients must be based on empirical data from experimental determinations. In fact, standards that describe use and limitations of electronic equipment in extremes of environmental conditions are not available. Suppliers of electronic equipment normally lack facilities for testing their products in controlled hypobaric atmospheres (4).

PROBLEM IDENTIFICATION

As air pressure decreases, dissipation of heat from electronic equipment slows. This results in an increase in operating temperatures and may likely cause erratic function and possible failure. Although there is no definative demarcation as to when failures begin to occur, the number of failures are proportional to the altitude extreme. Few operational difficulties occur below the air density of 980 gm/m^3 (3,000 meters - 10,000 ft) where natural convection remains adequate for heat transfer (assuming effective control of other physical and chemical properties of air). Erratic function, questionable data recordings, and some equipment failures are noted above 3,000 meters utilizing only natural convection. Significant equipment failures usually occur above 5,000 meters (16,000 ft) where air density decreases to 830 gm/m^3 and there simply is not sufficient air density to support natural convection. It is desirable to use forced convection between 3,000 and 5,000 meters while being essential above 5,000 meters. Current practice is to use small "boxer" fans (e.g., Pamotor, Model 7656, 4.5 in sq) to provide forced convection. This permits electronic equipment to function between 5,000 and 6,000 meters (16,000 and 20,000 ft), in a manner comparable to the performance found between 3,000 and 5,000 meters using natural convection. There is insufficient air density above 6,000 meters (750 gm/m^3) for even forced convection (using fans) to be effective.

The need to develop a new technology became necessary in order to conduct a biomedical research project designed to study human acclimatization from sea level to the simulated summit of Mt. Everest (5). The actual summit is determined to be 8,848 meters (29,028 ft) with a barometric pressure of only 250 mmHg (6). The air density is little more than 500 gm/m^3. A new method of forced convection was developed to cool electronic equipment required for data collection under these conditions.

SYSTEM DESCRIPTION

A Transvector *flo-gain nozzle* (*Vortec, Model 900*) is the essential component of this new technological system. The flo-gain nozzle directs a compressed air (60-80 psi) flow into a thin sheet, greatly increasing the velocity of the flow (Fig. 1). The rapid air flow accelerates surrounding air molocules to create a highly amplified, yet quiet flow. This impulse principle has been described similarly to a billiard break shot, where a single ball sets fifteen other balls into motion. Compressed air attains sonic velocity through an adjustable slot and attaches to the cone shaped exterior surface of the nozzle. A micrometer dial, used to throttle air velocities, allows adjustment from closed to .012 in. At sea level, compressed air output flows can be more than tripled because of entrainment. Although less induction occurs at altitude due to the decrease in air density, added entrainment still serves to enhance the cooling effects of the compressed air flow.

The system assembly (Fig. 2) begins with an air pressure regulator/filter (Norgren, Model B12-421), used to adjust line pressure and serves to filter out impurities e.g., water and oil, that could harm electronic equipment. Poly-flo tubing (Imperial Eastman, Model 44P) is used throughout the assembly because it resists embrittlement, swelling, flexural fatigue, and withstands a 200 psi burst pressure. The tubing passes through the hypobaric chamber wall using a pneumatic penetration bulkhead adaptor (Hubbell, Model SHC1035CR), providing for an uninterrupted feed-through of compressed air. A neoprene compression bushing with a nut, fits tightly around the tubing and effects a seal against atmospheric differential pressure leaks. On the inside of the hypobaric chamber, a manifold with shut-off valves provides a multible source for the transvector nozzles. Air flows may be directed on heat exchangers and power supplies, through ventilation ports and fan units, or into closed areas such as intact cabinets. The air stream may be adjusted to compensate normal atmospheric cooling for any combination of altitude and enviromental conditions.

No electronic instrumentation or other electrical equipment failures have occured while using the transvector cooling system. Research data were collected during multible human exposures at simulated altitudes up to 8,848 meters where it was believed that the normal function of electronic instrumentation would be marginal or dubious (5). Compared to fans, the compressed air system is inherently explosion proof (non-electrical); has no moving parts to fail; has quieter operation; has variable air flow output; requires no protective guards; produces

lower maintenance and operating costs; and has a greater capacity to cool equipment. The application of this cooling technology has opened new frontiers for hypobaric medicine, as well as environmental testing and equipment development activities. The development of a cooling system for electronic equipment in hypobaric chambers now makes it possible to expose data processing and biomedical instrumentation to the low pressure atmospheric conditions up to 9,000 meters, an accomplishment not previously possible.

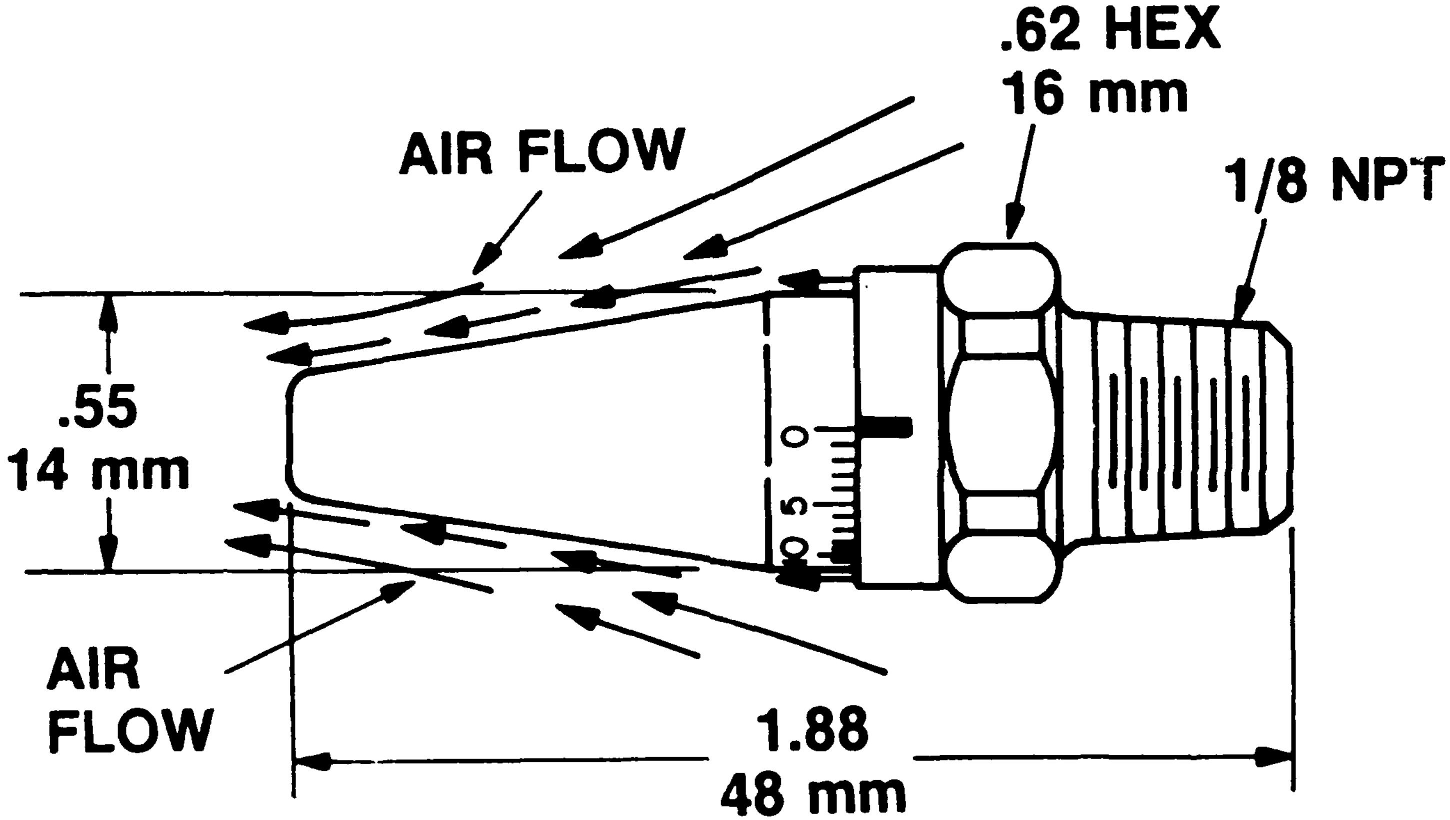

Fig. 1. Enlarged view of the Transvector flo-gain nozzle used to cool electronic equipment.

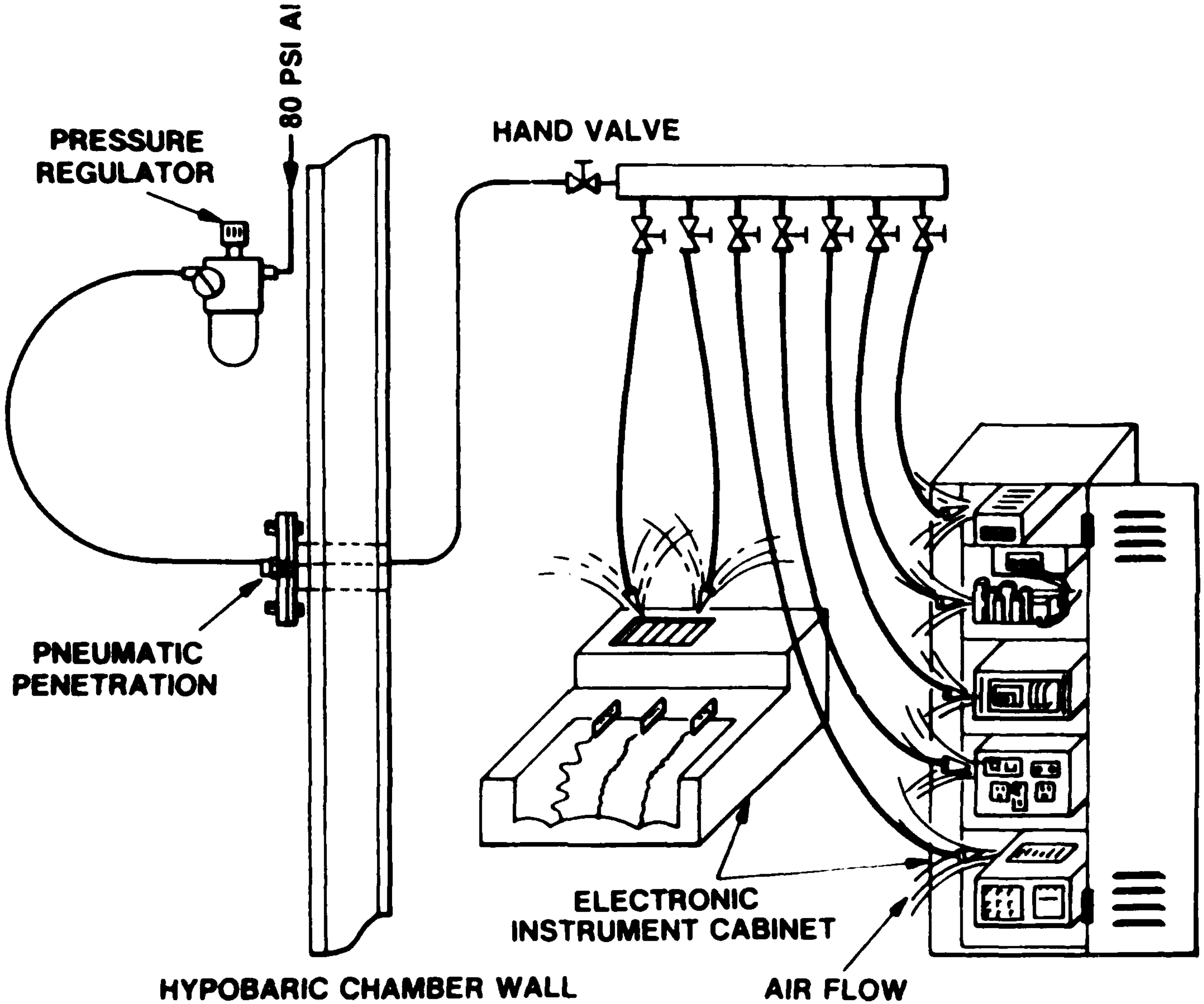

Fig. 2. The system assembly developed to cool electronic equipment operating in low pressure atmospheres of hypobaric chambers.

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